Final Memorandum Summarizing EMS ISP Study’s Follow Up Work

1 INTRODUCTION

In June 2021 the Massachusetts Program Administrators (PAs) approved the following research tasks for the EMS ISP study (MA20C03-B-EMSISP).

- **Brainstorming session:** This research task involved the study team convening a “brainstorming session” to discuss possible evidentiary standards for the baseline condition of EMS systems for use in custom EMS projects. This brainstorming session involved members of the evaluation team, PA representatives (both from evaluation and implementation), and representatives of the Energy Efficiency Advisory Council (EEAC). The evaluation team developed a discussion guide for the session, which was convened on June 11, and had a recording of the session transcribed. This summary memorandum (memo) is the main deliverable for this task.

- **Analysis of EMS front end screenshots:** This research task involved analyzing a sample of the photos and screenshots of EMS frontends that DNV had collected from EMS end users during virtual site visits that had been conducted for the EMS ISP study. The main research objective of this task was to determine the feasibility of using these screenshots/photos to assess whether these EMS systems are functioning in an optimal manner. The PA’s EMS Technical Advisor B2Q led the analysis with DNV providing logistical and analytical support.

2 KEY FINDINGS AND CONCLUSIONS

This section summarizes some of the key findings and conclusions from these two research tasks.

2.1 The Brainstorming Session

This section presents some of the key findings from the EMS ISP brainstorming session

2.1.1 EMS Failure

Some of the key takeaways from the brainstorming session on EMS failure included

- **Identifying equipment failure might be a substitute for measuring baseline operating conditions when measurement is difficult:** “[Equipment failure] might be a shortcut to defining what the baseline conditions might be,” said one session participant. However, one of the reviewers of a draft version of this memo questioned whether such indicators of system failure could be helpful in identifying the pre-existing operating conditions needed for estimating energy savings.

- **How to define system failure:** Some of the perspectives on how to define EMS failure included:
  
  - **System performance should be judged on a continuum:** One EEAC/PA representative said that when it comes to making upgrades to existing EMS systems the EEAC/PAs are not only interested in failed systems but also systems which fall into a spectrum of performance where failure is at one end of the spectrum.
  
  - **It is best to define EMS failure or non-performance holistically rather than focusing on specific hardware failures:** “When we’re distinguishing between hardware failure and the system no longer meets the need,”
said one EEAC/PA representative, "it is definitely not just hardware. It's the components. It's the sequences. It's the way that the system is operating."

- **The inability of equipment to be controlled optimally as an interpretation of failure.** One EEAC/PA representative said that the inability of equipment to be controlled optimally should be the criteria for EMS replacement rather than equipment failure per se.
- **There are gradations to defining controls as having failed:** One EEAC/PA representative classified EMS controls as being in three categories: 1) controls that can be optimized at minimal cost, 2) controls that can be optimized with a more significant investment, and 3) controls that cannot be optimized and must be replaced.

- **Indicators of system failure:** The participants in the brainstorming session identified several indicators of failure of EMS control components or hardware that would benefit from replacements/upgrades including:
  - The inability of the EMS to accurately read outdoor temperatures or building pressure
  - Failures of sensors and actuators (there was discussion as to whether there should be a defined percentage of failed sensors/actuators which could classify the system as failed)
  - Outdated software which impacts the unitary controller or master panel functionality
  - Controls too old to allow programming of energy-saving sequences (one EEAC/PA representative suggested that reviewing cut sheets for controllers can reveal their capability for programming)
  - Pneumatic controls
  - The loss of building static pressure
  - The age of the system (there was agreement that while system age by itself did not mean an EMS had failed, it could be a helpful indicator)

  However, one reviewer of the draft version of this memo questioned whether the inability of the EMS to accurately read outdoor temperatures or building pressure were reliable indicators of system failure.

- **However, the loss of frontend visibility to the EMS system or outdated software do not necessarily constitute system failure:** EEAC/PA representatives observed that equipment can still be controlled in energy saving ways if frontend visibility is lost or software is outdated. One commenter on the draft version of this memo acknowledged while this was true, there was likely a high correlation between the failure of the EMS front end and the loss of functionality for the controls in maintaining the sequence of operations.

### 2.1.2 How to Establish an EMS Baseline

Some of the key takeaways from the brainstorming session on establishing an EMS baseline included:

- **Understanding HVAC system operation is the key to establishing a baseline, but it is difficult to get detailed HVAC pre-data.** The EEAC/PA representatives observed that HVAC system operation accounts for the largest share of potential energy savings from EMS systems and therefore should be the primary target of any baseline measurements. However, they also acknowledged acquiring these data is difficult. "Trying to ascertain the details of how an existing EMS is controlling a complicated HVAC system and from that gleaning how much energy that system is using, from experience, that is a no-start kind of a situation," said one representative.

- **RCx might be the least expensive way of determining the baseline operating conditions, but some customers do not have the patience for it:** Some EEAC/PA representatives thought that retrocommissioning might be the most efficient way to define baseline energy savings. However, they also observed that many customers do not have the patience for RCx and would rather just get a new EMS.
• **Taking screenshots of EMS frontends is a low-cost way to learn something about baseline operating conditions:** “I think in some cases, you can take screenshots, and you can capture the existing programming that’s being done with the help of a controls contractor to document how that existing sequence is performing,” said one EEAC/PA representative.

• **Average savings estimates from past projects could be a starting point for PAs to discuss the level of potential program support with customers:** “We assume we can save at least 10% on the HVAC system load or the load of the increment that we’re controlling and have a pretty good model, so we can come up with a reasonable estimate of what that [savings] was,” said one EEAC/PA representative. “And then that would give us some numbers that we, the customer and the program administrator could use to figure out: What’s the cost-effective point or level that the program can support this customer in their upgrade?”

• **Permanent metering may be a tool for doing pre- and post-measurements:** “We can install permanent metering [on an EMS] … it’s a serious and extremely useful tool for this type of work,” said one EEAC/PA representative. “And it doesn’t really cost more than hiring people to go out and put on [temporary] meters and take them off. And it becomes a permanent solution.” In commenting on the draft version of this memo, one commenter noted that some of the PA’s offer on-bill financing of submeter installation for their customers.

• **Billing analysis may be helpful for measuring savings:** One evaluation team member observed that the EMS/RCx vendors who were interviewed for the EMS ISP study estimated average energy savings for RCx of 13%. Another evaluation team member said that this level of savings is capable of being detected by billing analysis.

• **While measuring the baseline conditions can be expensive, there is also a cost to not doing this measurement:** “I get that we’re going to call [pre- and post-measurement] expensive,” said one EEAC/PA representative. “But what’s really expensive are terrible [project] realization rates, because we don’t know. And so that’s a bunch of savings that typically we’re losing, because we’re not measuring before, and we’re not measuring after.”

• **Determining baseline conditions are difficult when new owners acquire buildings not recently occupied:** One EEAC/PA representative noted it was difficult to determine the baseline operating conditions of an EMS in scenarios where customers acquire buildings which had not recently been occupied.

• **Massachusetts’ current protocols for defining baselines for VFDs could potentially be applied to EMS systems:** One member of the evaluation team observed that Massachusetts allows the baseline for VFDs to be the existing equipment without VFD control if the end user has not replaced non-functional equipment after two years and suggested that something similar could be done with EMS.’

### 2.2 The Analysis of Screenshots of EMS Frontends

From the self-selected screenshots provided and self-described as operating “optimally” by the customer, B2Q’s analysis concluded that several of the systems are likely not operating “optimally.” Common issues found within the provided screenshots included potential sensor calibration issues, difficulty maintaining temperature and pressure setpoints, failed actuators, the potential to reduce heating/cooling loads, and the lack of more advanced energy efficiency strategies. B2Q concluded that it is likely that during the survey process key aspects of a system can be overlooked by the customer when determining “optimal” operation (System & Energy Efficiency). It should be noted that this analysis was a first look at the system using this screenshot review to gain a high-level summary of potential issues and operating conditions. As a result, the findings listed within the document are constrained by the limited information available at the time of review. B2Q concluded in most cases that the screenshot information was not enough to determine if the systems were running optimally. In all cases, additional analysis of the building, programming, and sequences is required to gain a better understanding of the systems operating conditions.
3 METHODOLOGY

This section provides more details on how the information for these two add-on research tasks was collected and analyzed.

3.1 The Brainstorming Session

In preparation for the brainstorming session, the study team distributed a PowerPoint slide deck to the PA and EEAC representatives to serve as a discussion guide. The topics covered by this discussion guide included:

- Background and scope for the discussion including a summary of the baseline framework
- A summary of how the EMS/RCx vendors who were interviewed for the EMS ISP study defined EMS failure
- Discussion questions on how to define EMS failure
- A summary of the pros and cons of data-driven approaches for identifying baseline EMS operating conditions
- Discussion questions about data-driven approaches for identifying baseline EMS operating conditions
- A summary of possible questions for inclusion in an end user survey to identify baseline operating conditions
- A summary of other possible information sources for identifying EMS baseline operations

The hour-long brainstorming session took place on June 11, 2021 and included the participation of nearly two dozen individuals. The study team recorded the discussion and had the audio recording transcribed. This transcript was the starting point for the analysis of the discussion in this memo.

3.2 The Analysis of Screenshots of EMS Frontends

A central objective of this research task was to assess whether end user claims that their EMS systems were functioning in an optimal manner could be assessed through an analysis of the screenshots/pictures of the frontends of their systems. The work scope for this research task called for DNV to randomly select five EMS end user sites from the subgroup of 15 end users who had said that their EMS/BAS was functioning in an optimal manner. After DNV had selected these five sites and provided B2Q with the screenshots/pictures, B2Q determined that for two of the sites the information in the screenshots/pictures were insufficient to make an adequate determination of EMS functionality. DNV then provided B2Q with two replacement sites.

B2Q then analyzed the screenshots/pictures for these five sites. For each site, B2Q tried to answer the following questions:

- Whether there was adequate information from the frontend photos/screenshots to determine if the system is operating in an optimal manner
- [IF THERE WAS ADEQUATE INFORMATION] What conclusions could be drawn from the EMS frontend photos/screenshots about whether the EMS was functioning in an optimal manner.
- [IF THERE IS NOT ADEQUATE INFORMATION]
  - What information is missing for determining whether the EMS is functioning in an optimal manner.
  - Whether it appears that there might be an opportunity to recontact the end user to collect the missing information (e.g., by asking them to drill down further on a given screen)

It is important to note that in most cases the end users selected which screenshots to send the evaluation team. In addition, the end users were not asked to provide sequences of operations, drawings, programming logic, etc. to determine whether equipment was operating “optimally.” Furthermore, trend logs would be required to determine if the

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1 The interview question was: “Is your company’s EMS/BAS functioning in an optimal manner?”
equipment was actually operating according to intended sequences. Collecting this information would likely require an RCx or monitoring-based commissioning (MBCx) study of the buildings to determine whether they were truly operating “optimally” and where there might be opportunities to improve.

B2Q also concluded that while in all cases there was an opportunity to recontact the user to obtain additional missing screenshots and more fully understand the system, with this providing more information about the system, the additional documentation and trend logs mentioned previously would be needed to do a rigorous analysis of the EMS operation. B2Q also questioned whether additional screenshots would be necessary unless a full RCx study was intended. It believed there was enough evidence from the previously provided screenshots to conclude that many of these systems are not functioning “optimally” despite being described as such.

4 FINDINGS

4.1 Findings from the Brainstorming Session

This section summarizes the brainstorming discussion.

4.1.1 Discussion Scope

The evaluation team explained that the discussion would be limited to custom projects for EMS systems in existing buildings. The team noted that the PAs have expressed interest in improving the EMS prescriptive programs but the issues in defining baselines for a prescriptive program are different than those for a custom program. The team also observed that while there was merit in exploring EMS energy savings opportunities in new construction, due to the full agenda for of the current brainstorming session, this should be done in a separate discussion.

4.1.2 EMS Failure

The evaluation team first presented a slide showing how the 17 EMS/RCx vendors they had interviewed for the EMS ISP study had defined system failure. The slide showed that most of the vendors defined failure as equipment failure leading to the loss of system control. However, a few mentioned situations where system control was still in operation but the existing sequence of operations (SOO) no longer suited the facility or the equipment being controlled was no longer operating according to the designed control schemes. The team observed that RCx might be able to correct these latter scenarios.

Some of the key points made in the discussion of EMS failure included:

- **System performance should be judged on a continuum**: One EEAC/PA representative said that when it come to making upgrades to existing EMS systems the EEAC/PAs are not only interested in failed systems but also systems which fall into a spectrum of performance where failure is at one end of the spectrum. “In general, the systems have some operations, so it’s nuanced,” the representative explained.

- **Loss of frontend visibility to the EMS system alone should not constitute system failure**: “If you have a frontend that isn’t working, but the equipment itself and the associated controller are still controlling the equipment in the way that it needs to be in order to save energy,” said one EEAC/PA representative, “then the actual panel itself and the sensors did not fail. As long as the sequence is programmed in that panel, it’s operating in the way that it’s anticipated.”

- **Outdated software may not necessarily cause reduced system performance**: One EEAC/PA representative pointed out that while outdated software may cause problems with the customer using the EMS front end, this does not necessarily prevent the EMS from doing it’s expected control functions. The representative elaborated:

  > if it’s an outdated software, does that inhibit the system from carrying out the sequences of operation that make the system run? For example, if it’s Windows 13, and it needs to be Windows 14, does that mean that because of the operating system it’s connected to, does that mean all the panels are going to fail and make the system not run? That’s a frontend issue. It’s not an issue that impacts the equipment at the
level where the programs are stored. So, if the programs are stored in the controller, then having a frontend that’s not operating, yes, the end user can’t see it, but that’s not impacting what’s going on at the chiller or the boiler that are connected to the panel over in the mechanical room.

- **However, there are scenarios where outdated software can lead to system failure:** One EEAC/PA representative identified two scenarios where software failure would lead to equipment failure including:
  - “If the unitary controller has outdated software, and that’s causing conflict because it can’t connect to some BACnet communication … then that software in the panel is going to cause failure,”
  - “If the master panel that connects the outdoor air temperature to all the other air handling units to help it communicate, and that fails, and there’s no backup or redundancy, then, yes, I can see where those would cause failure in the system.”

- **It is best to define EMS failure or non-performance holistically rather than focusing on specific hardware failures:** “When we’re distinguishing between hardware failure and the system no longer meets the need,” said one EEAC/PA representative, “it is definitely not just hardware. It’s the components. It’s the sequences. It’s the way that the system is operating.”

- **Identifying equipment failure might be a substitute for measuring baseline operating conditions when measurement is difficult:** “I think the problem is that’s it’s a pretty tough standard to … determine what that baseline energy use is,” one evaluation team representative commented. “We could just walk away from [looking at equipment] failure … but there was some thought that [equipment failure] might be a shortcut to defining what the baseline conditions might be.” However, one reviewer of a draft version of this memo questioned whether such indicators of system failure could be helpful in identifying the pre-existing operating conditions needed for estimating energy savings.

- **The inability of equipment to be controlled optimally as another interpretation of failure.**
  - One EEAC/PA representative said that the inability of equipment to be controlled optimally should be the criteria for EMS replacement rather than equipment failure per se. “You can repair controllers, you can replace one,” said the representative. “But if you can’t implement an optimized sequence of operation, which is what we need to be doing in these buildings, then that is a good indication that we need to replace the legacy building automation system, regardless of the fact that it may still be running fans or doing all of the other things that it’s doing at some level. It can’t be optimized.”
  - Another EEAC/PA representative agreed with this position: “So if [the EMS] it can’t be optimized, or it can’t be retro-commissioned, then, for the purposes of the program, it would be failed.”

- **The relationship between system age and system failure:** One EEAC/PA representative wondered whether there was a correlation between EMS age and system failure. The evaluation team noted that the EMS ISP study had found that the average age of EMS systems that fail was 17 years according to the EMS/RCx vendors it interviewed. The team also observed that recent data from ASHRAE came up with a similar estimate (18 years) for the median age of EMS systems upon removal based on 24 observations.

This same EEAC/PA representative suggested that the age of the system could be used as a justification for EMS replacement: “Let’s say if the’ customer says: ‘Oh, we have an old system,” whether the system is doing all it needs to do or not,” the representative said, “. . . but it’s an old system, and it’s beyond its measure life. … [In these cases] Let’s do it. It’s a replacement, because of … the age of the equipment.” One commenter on the draft version of this memo noted that this scenario would qualify as natural replacement where the baseline would be a new EMS rather than the existing EMS.

The evaluation team observed that for some customers it may be difficult to determine the age of the EMS due to the facility staff involved with the system installation no longer being around. However, it might be possible to
determine this through further research (e.g., model name, serial number on nameplate). The EEAC/PA representative wondered if the evaluation team would require some proof of system age through photos, etc.

Another EEAC/PA representative was concerned as to how evaluators might weigh in on the appropriate baselines for these older EMS systems. “One of the risks that the PAs are going to see around legacy EMS replacements will be the potential for evaluation to come back and say: ‘Well, you know, that equipment was going to be replaced anyway, so your baseline is a new system, effectively,’” said the representative. “So, I think that, defining how the PAs can document for evaluation that, in fact, there’s a legitimate retrofit here with the pre-existing condition baseline is very important.”

- **The inability of the EMS to accurately read outdoor temperatures or building pressure may be indicators of system failure:** “If we’re looking for a certain component of an EMS whose failure would be a tell-tale sign, I would think that would be an outdoor temperature sensor,” said one EEAC/PA representative. “The system wouldn’t be responding to temperature changes, and I think that would be a great way to tell if an EMS is working or not.” Another EEAC/PA representative confirmed the importance of the failure of these sensors. “Universal sensors like the outdoor air temperature or the building pressure are some of the most impactful because they impact the entire building, and sometimes they don’t have redundancy,” said the representative. However, one reviewer of the draft version of this memo questioned whether the inability of the EMS to accurately read outdoor temperatures or building pressure were reliable indicators of system failure.

- **Failures of sensors and actuators are other indicators of system failure:** “As far as the most common sources of failure, I would like to add in sensors and actuators, I think they’re the most common,” said one EEAC/PA representative.

- **The loss of building static pressure is another indicator of EMS failure:** “Another indication [of EMS failure] would be it drops the static pressure of the building down,” said one EEAC/PA representative.

- **There are gradations to defining controls as having failed:**
  - One EEAC/PA representative classified EMS controls as being in three categories: 1) controls that can be optimized at minimal cost, 2) controls that can be optimized with a more significant investment, and 3) controls that cannot be optimized and must be replaced.
  - Another EEAC/PA representative observed that just because controls are still working does not mean that they can provide energy saving operations. “There are controllers that are 10 or 15 years old … and they weren’t allowed to have program sequences in there,” said the representative. “Now some of the [EMS] programs are open software where people can program [SOO] in. But [for energy savings] you need sequences that go above and beyond.”

### 4.1.3 How to Establish an EMS Baseline

The evaluation team then presented some slides showing the pros and cons of collecting different types of information for estimating the baseline operating conditions of EMS systems. Some of the key points made in the discussion of EMS baselines included:

- **HVAC system operation being the key to establishing a baseline:** “Establishing a baseline is really about documenting the pre-existing energy consumption over the range of loads that HVAC systems see in the course of a year,” said one representative. “So, I think there’s two pieces. There’s: ‘What is the evidence that this is an energy efficiency-driven retrofit?’ and then: ‘What is the technical approach to establishing the energy consumption associated with the HVAC systems affected in the pre- and post-condition?’ … I don’t care what the EMS is doing. I care how much energy the HVAC system is consuming. And typically, there’s major pieces of equipment that are the biggest loads in the HVAC systems.”
• The difficulty of getting detailed HVAC pre-data. One EEAC/PA representative said that it will be difficult to get detailed pre-data on how the EMS was controlling the HVAC system and therefore it might be necessary to find proxies for these HVAC operation data: “We would potentially have limited data in the pre-[state], … It’s not like we’re going to have the whole year of data,” said the representative. “We need some proxy for that. … what we’re talking about is: What’s the proxy? … trying to ascertain the details of how an existing EMS is controlling a complicated HVAC system and from that gleaming how much energy that system is using, from experience, that is a no-start kind of a situation”

• While measuring the baseline conditions can be expensive, there is also a cost to not doing this measurement: “I get that we’re going to call [pre- and post-measurement] expensive,” said one EEAC/PA representative. “But what’s really expensive are terrible [project] realization rates, because we don’t know. And so that’s a bunch of savings that typically we’re losing, because we’re not measuring before, and we’re not measuring after.” However, one commenter on the draft version of this memo asserted that not having pre-measurements does not necessarily lead to bad realization rates (since evaluators try to model the previous operating conditions as best they can) and that a more common cause of low realization rates is the discovery that the end user had similar controls in place before installing the new EMS.

• Controls too old for energy-saving sequences could be one baseline indicator: One EEAC/PA representative said that the presence of controls which are too old to allow for energy-saving programming could be one indicator of a baseline EMS system with little energy savings functionality. “There are controllers that are 10 or 15 years old … and they weren’t allowed to have program sequences in there,” said the representative. “So, if you know you have a legacy system that doesn’t allow for programming, then there’s a reasonable chance that that system wouldn’t allow for some of the energy savings.”

• Pneumatic controls might be another baseline indicator: One EEAC/PA representative said that the presence of pneumatic controls could be one indicator of possible future savings. “I’m thinking about the pneumatics, because I think those are key, potential key targets for the PAs to team with vendors on,” said the representative. “And, so, what’s the potential there? … my sense is that we could probably do some lit review for pneumatic controls upgrade. My gut sense is you’re going to see at least a 10% energy savings.”

• RCx might be the least expensive way of determining the baseline operating conditions and energy usage, but some customers do not have the patience for it:
  - “We do have the ability to … incentivize the investigation [of baseline conditions] through our RCx pathway already,” said one EEAC/PA representative. “And so that’s … probably the most efficient way of finding out what’s there and then going forward in determining the savings. … I think that we would like to approach it with retro-commissioning, if possible. And then, if the system does not have the capacity to program the sequences, then, yes, by all means, let’s give them the ability to program those sequences with whatever is needed to do that.”
  - However, the representative observed that some customers do not have the patience for RCx. “The problem is that you tell [the RCx option] to a customer, and the customer says: ‘Well, rather than figure out about that, we’re just going to go ahead, and we want a new system,” said the representative. “Some customers are willing to go through the [RCx] process, and their system is relatively new. And then you have other customers who have functioning actuators that may or may not be pneumatic and may or may not function. But they say: ‘Oh, the system is old, and this vendor said that I could get a new EMS, and you guys are going to give us an incentive.’”

• Determining baseline conditions are difficult when new owners acquire buildings not recently occupied: One EEAC/PA representative noted it was difficult to determine the baseline operating conditions of an EMS in scenarios where customers acquire buildings which had not recently been occupied. “It becomes a unique situation to try to sort out,” said the representative “What you’re hearing from the customers that the system that is there is
failed, but it’s difficult to prove, and also because they’re the new owners, they want to start fresh with a new system.”

- **Whether to deem a non-controlling EMS to be the baseline condition if the system had not been functional for a while:**
  
  o One member of the evaluation team observed that Massachusetts allows the baseline for VFDs to be the existing equipment if the end user has not replaced non-functional equipment after two years and suggested that something similar could be done with EMS.
  
  o However, one EEAC/PA representative thought that if the EMS sequence of operations indicates that the end user had intended to gain energy savings from a piece of equipment, the end user should not be able to claim savings for a piece of failed equipment that they should have replaced anyway. “If they have an existing outside air reset on their chilled water, for example, and their outside air sensor is broken, then the question becomes: ‘Can you really claim savings for just replacing the outdoor air sensor?’” said the EEAC/PA representative. “I would say, no, because they already had the sequence, and they really should have replaced the sensor.”

- **Identifying equipment failure might be a substitute for measuring baseline operating conditions when measurement is difficult:** “I think the problem is that it’s a pretty tough standard to … determine what that baseline energy use is,” one evaluation team representative commented. “We could just walk away from [looking at equipment] failure … but there was some thought that [equipment failure] might be a shortcut to defining what the baseline conditions might be.”

- **Average savings estimates from past projects could be a starting point for PAs to discuss the level of potential program support with customers:** “We assume we can save at least 10% on the HVAC system load or the load of the increment that we’re controlling and have a pretty good model, so we can come up with a reasonable estimate of what that [savings] was,” said one EEAC/PA representative. “And then that would give us some numbers that we, the customer and the program administrator could use to figure out: What’s the cost-effective point or level that the program can support this customer in their upgrade?”

- **Billing analysis may be helpful for measuring savings:** One evaluation team member observed that the EMS/RCx vendors who were interviewed for the EMS ISP study estimated average energy savings for RCx of 13%. Another evaluation team member said that this level of savings is capable of being detected by billing analysis.

- **Permanent metering may be a tool for doing pre- and post- measurements:** “We can install permanent metering [on an EMS] … it’s a serious and extremely useful tool for this type of work,” said one EEAC/PA representative. “And it doesn’t really cost more than hiring people to go out and put on [temporary] meters and take them off. And it becomes a permanent solution.” In commenting on the draft version of this memo, one commenter noted that some of the PA’s offer on-bill financing of submeter installation for their customers.

- **Taking screenshots of EMS frontends is a low-cost way to learn something about baseline operating conditions:** “I think in some cases, you can take screenshots, and you can capture the existing programming that’s being done with the help of a controls contractor to document how that existing sequence is performing,” said one EEAC/PA representative. Another representative agreed: “[Frontend screenshots] are not always 100% accurate, but they can provide a guide to what is in the actual system, and then you can see what’s been programmed with the technician to determine what that sequence is.”

- **Cut sheets for controllers can reveal their capability for programming:** “If you’re looking for whether or not the controller has the capacity to take programming and adjust it or optimize it,” said one EEAC/PA representative, “you can certainly use the cut sheets of the controller to determine the functionality.”

- **High-level indicators of HVAC system energy consumption can help customers understand whether EMS changes can save energy:** “Customers don’t want to look at how many kWh a fan is using,” observed one EEAC/PA
representative. “But if you can come up with a metric for a system, so we would typically use a kW per ton for a chiller system … that really helps them figure out what’s happening with their chiller plant.”

4.1.4 Other Discussion Topics

Other discussion topics included:

- The need for customer education: “Vendors are just selling stuff, and this is a major and complex investment, so hopefully, some customer education there would help,” said one EEAC/PA representative.

- For optimizing controls there are both basic and advanced strategies: “If we’re talking about schedule changes, that [control strategy] is a couple decades old,” said one EEAC/PA representative. “And, yes, we still want to do those, because they’re cheap and easy savings, but they’re not optimization.

- What incentives the custom EMS programs can offer: One EEAC/PA representative indicated that knowing which pieces of the EMS can be incentivized is important. “In the end the customer is going to want to know about the incentive,” the representative said. So, we haven’t really talked about the incentive for the cost side … what pieces [of the EMS] can we pay for?”

4.2 Findings from the Analysis of Screenshots of EMS Frontends

This section first provides a summary of findings from the analysis of screenshots of EMS frontends. Then it provides a more detailed analysis of each of the five sites which includes sample screenshots. Finally, it provides some conclusions from this analysis.

B2Q analyzed screenshots from five example buildings and found common issues within the provided screenshots for each building, including those related to sensor calibration issues, not meeting temperature and pressure setpoints, failed actuators, and missed opportunities to reduce heating/cooling loads. The results from B2Q’s analysis suggest that several of the systems which customers described as operating “optimally” were likely not operating “optimally”.

It should be noted that “optimal” is a subjective term that can take on different meanings for various customers. Customers often focus on whether their building zones are meeting setpoints and occupants are comfortable. As a result, system and energy efficiency can sometimes be overlooked by customers during the evaluation process.

The following analysis is a first look at the system to gain a high-level summary of potential issues and operating conditions. As a result, the findings listed within the document are constrained by the limited information available at the time of review. In all cases, additional analysis of the building, programming, and sequences is required to gain a better understanding of the systems operating conditions.

In each of the sections related to each of the buildings, two key questions are first summarized:

1. Was adequate information provided to make an assessment of whether the BAS is performing “optimally”?
2. Does the equipment shown appear to be operating “optimally”?

Examples of some of the key findings are listed below.

- Hotel:
  - RTU-401 enables electrical reheat during cooling mode due to the unit not properly modulating the outdoor air damper and causing the supply air temperature to overshoot its cooling setpoint.

- Middle School/High School
  - The West Boilers are operating at a supply setpoint that is higher than the Hot Water supply setpoint which appears to be unnecessary and causes mixing of the HW supply and return loops. Reducing the boiler supply setpoint to match the HW supply setpoint would reduce the heating load on the boilers.
DT Supply temperature appears to be much higher than what is needed at the end use. Consider reducing the supply temperature to better match what is needed at the end use to reduce heating load on the boilers.

RTU-12 appears to have an unexpected temperature drop of 14°F across the cooling coil when the cooling valve is commanded closed. This may be increasing the load on the heating coil.

The reheat valve for the VAV box serving Rm. E151W Hall was commanded fully open but a temperature rise across the coil was not observed.

**Healthcare Building**

- The RTUs serving the building appeared to not meet their respective duct and zone static pressure setpoints by at least 0.2” and 0.06” respectively.
- RTU-2 is reading an unusually high mixed air temperature of 86.2°F. Both the Return and Outdoor air temperatures are below 68°F, therefore there might be a sensor calibration issue.
- The HW Return loop appeared to read a 31°F temperature rise, possible sensor calibration issue or HW Supply loop is leaking into the return loop.

**Commercial Building**

- RTU-1 & 2 were recording supply air temperatures that were ~12°F greater than the setpoint of 60°F.
- The building pressure setpoint was indicated to be 0.05” but the building pressure was reading about neutral.
- A VAV box was recording airflows of 471 cfm with the damper fully closed indicating that the damper actuator may have failed.

**Ski Resort**

- The duct static pressure for RTU-3 & 15 were reading 0.41” below the required static pressure setpoint.
- RTU-14 was recording the supply air temperature 18°F greater than setpoint.
- The heating alarm for RTU-3 was activated.
- The outdoor air damper position for RTU-8 was reading 0% open when the minimum damper position was indicated to be 10%.
- RTU-3 was reading supply air temperatures ~2°F below the return air temperature while the heating command was enabled and the cooling coils were commanded off. This may indicate that the cooling coils are leaking, or the supply air temperature sensor is mis-calibrated.
1 APPENDIX A: DETAILED SITE-LEVEL FINDINGS

This subsection provides more details on the findings summarized in the previous subsection.

1.1 Hotel

Findings from B2Q’s analysis of screenshots from an EMS system installed in a hotel included:

- **Was adequate information provided?** No. Only four screenshots were received. These did not include information on the exhaust fans, condenser loop, MAU 401 & 402, the energy recovery unit, and the AC split system units.

- **Was equipment operating optimally?** Some issues may be present based on the very limited screenshots received. The key issues are listed below, however additional findings are listed with the individual screenshots.

- **Heating and cooling setpoints:** On RTU-401, the outdoor air damper is not modulating properly and causing the supply air temperature to overshoot the cooling setpoint. This results in the electric reheat activating while cooling mode is enabled.

- **DAT reset:** Review operation of RTU-401 and the potential to incorporate a discharge air temperature (DAT) reset sequence.

Figure 1 shows one of the screenshots from the hotel’s EMS. The B2Q team concluded that to allow for a more complete screenshot analysis, the following screenshots would be helpful: Condenser Loop, RTUs 401 & 402, MAUs 401 & 402, Energy Recover Unit, Split AC units 1-3, Building Exhaust Fans (EF), Basement Sump Pumps, Hydronics, Floors 1-3 (East & West), & the Roof.
Figure 1: Screenshot 1 from Hotel EMS

Figure 2 shows another screenshot from the hotel’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- The return air temp. of 71.4F should activate the cooling mode but heating is enabled due to the supply air temperature (SAT) being lower than setpoint (SAT-SP).
- The outdoor air damper (OA-DPR) is not at minimum position while the SAT is overshooting its SAT-SP. Modulating the OA-DPR to a minimum position during these instances would reduce overshoot decreasing the unnecessary heating required to raise the SAT back to SAT-SP.
- There is no indication of a DAT reset sequence.
- The supply fan is running at a high speed when compared with the return fan which may be an issue of concern.
- The differences between the return and reference space temperatures are potentially high, which may indicate a slight miscalibration.
Figure 3 shows another screenshot from the hotel’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- The supply fan is operating at 36% speed when the discharge static pressure is 0.2” above setpoint, so there may be room to decrease fan speed.
- The zone static pressure typically should be meeting the static pressure setpoint with the OA damper at 75% open and the return fan off.
Figure 4 shows another screenshot from the hotel's EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- There is only a 7F temperature rise across the boiler, which is lower than typical.
- The boiler discharge temperature appears to be 66F which is low with many stages of heating on.
- Heat pump loop supply temperature appears to be 59F which is low, putting more work on the heat pumps.
Figure 4: Screenshot 4 from Hotel EMS
1.2 Middle/High School

The findings from B2Q’s analysis of screenshots from an EMS system installed in a middle school and high school included:

- **Was adequate information provided?** No, the screenshots provided did not include information for the Heat Recovery Units, MAU serving the kitchen, chiller system, and exhaust fans.

- **Was equipment operating optimally?** Some issues may be present based on the limited screenshots received. The key issues are listed below however, additional findings are listed with the individual screenshots.
  
  o **Boiler supply temperature:** It appears that the West boilers are operating at supply setpoints greater than the hot water setpoints. This merits a review to determine if the boiler setpoint can be reduced to minimize unnecessary heating.

  o **DT supply temperature:** It is worth reviewing and determining if the supply temperature can be reduced to better match what is being used at the radiant loop to reduce unnecessary heating.

  o **Economizer/cooling sequence:** There is an unexpected dT of 14F across the cooling coil on RTU-12. It is unclear if this is being caused by leaking OA damper, a leaking cooling coil, or a mis-calibrated airflow station. Therefore, it is worth examining the OA damper, cooling coil valve, and airflow station to determine if repairs need to be made.

  o **Reheat valve repair:** There was no change in temperature across the reheat valve on VAV box serving E151W Hall with the valve fully open. Therefore, it is worth reviewing the heating valve to determine if repairs need to be made.

Figure 5 shows one of the screenshots from the middle/high school. The B2Q team concluded that to allow for a more complete screenshot analysis, the following screenshots would be helpful: Heat Recovery Units (HRUs) for the A, B, & C Wings & the Lockers, Roof-Top Units (RTUs) 1 - 13, MAU-1, VAV boxes for all HRUs & RTUs 1-3, 6-8, & 11-13, Boiler system, Chiller System, Building Power Meters, Fan-Coil Units for classrooms A - C, HVAC1, Miscellaneous Exhaust Fans, Cabinet Unit Heaters/Miscellaneous heating, Building Alarms, and Radiant Slab zones.
There are multiple zones reading zone temperatures which are quite different, some as low as 61°F. It should be investigated whether this is acceptable for a setback temperature for these spaces (if these are still in setback mode at this time), and the variance in temperatures.

Zone 149 appears to be detecting -471 ppm, this appears to be a sensor calibration issue which could be altering intended demand-controlled ventilation sequences.
Figure 6: Screenshot 2 from Middle/High School EMS
Figure 8 shows another screenshot from the middle/high school’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- The dT between the boiler supply and return is ~11°F which is lower than typical.
- Information regarding stack temperature, Stack O2 content, and combustion air damper position was not found but would be useful in determining the operation of the boiler system.
- The boiler room CO is reading -58 ppm, the CO sensor appears to be mis-calibrated.
Figure 9 and Figure 10 show additional screenshots from the middle/high school’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- The boiler supply temperature is reading ~6°F below setpoint. The boilers appear to be heating water to 161°F then mixing with return water to meet the hot water supply temperature of 157°F, which seems to be unnecessary. Setting the boiler supply temperature to equal the hot water supply temperature could reduce unnecessary heating and mixing.

- Information regarding stack temperature, Stack O2 content, and combustion air damper position was not found.
Figure 11 shows another screenshot from the middle/high school’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons: The supply temperature for the unit at the right appears higher than expected when the associated fan is off, the heating valve appears to be closed, and the space temperature is at 67.5F.
Figure 12 shows another screenshot from the middle/high school’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- The supply temperature for the West wall seems unusually high in relation to the valve command of 39% when compared with the other zones. Investigating the size and type of each valve would help determine if these are accurate.

- The difference between the return temperature for the Left Side Main Lobby Radiant and the floor temperature is unusually high, ~6°F, which may be due to slight temperature miscalibration.

- Dual Temperature (DT) Supply and Boiler Supply Temperatures seem high for what is being used at the zones. Decreasing the supply temperature setpoint would reduce unnecessary heating.

- Information regarding flow and/or differential pressure to each zone was not found in screenshot. Information regarding flow can be helpful in determining if zones are receiving the correct amount of HW and if actuators are broken.
Figure 12: Screenshot 8 from Middle/High School EMS
Figure 13 shows another screenshot from the middle/high school’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- Min. OA Damper position is set to 10% but the economizer position is reading 0% and the OA airflow is reading 0 cfm.
- The cooling demand and economizer position are reading 0% but there is a 14°F temperature drop across the cooling coil. Possible reasons may include a mis-calibrated outdoor air airflow station, leaking cooling coil, and/or leaking outdoor air damper. One of these issues may be increasing the load on the heating coil.
- The unit appears to be overridden in occupied mode.

Figure 13: Screenshot 9 from Middle/High School EMS

Figure 14 shows another screenshot from the middle/high school’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons: The reheat valve is 100% open but the dT across the VAV is ~0°F. This appears to be causing possible comfort issues as the space temperature is ~3°F below the minimum space setpoint and ~5°F below the current heating setpoint.

Figure 14 shows another screenshot from the middle/high school’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons: The reheat valve is 100% open but the dT across the VAV is ~0°F. This appears to be causing possible comfort issues as the space temperature is ~3°F below the minimum space setpoint and ~5°F below the current heating setpoint.
Figure 15 shows another screenshot from the middle/high school’s EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons: It appears that ~8 zones are under heated by at least 3F. Three zones, WHV04, WHV05, & WU123, also appear to be overheated by ~5F.
Figure 15: Screenshot 11 from Middle/High School EMS
1.3 Healthcare Building

The findings from B2Q’s analysis of screenshots from an EMS system installed in a healthcare building included:

- **Was adequate information provided?** It is unclear if all information was provided as an overview screenshot of the BAS system was not included in the information given.

- **Was equipment operating optimally?** Some issues may be present based on the limited screenshots received. The key issues are listed below. However, additional findings are listed with the individual screenshots.
  
  - **RTU duct static pressure:** All RTUs appear to not meet their respective static pressure setpoints. The minimum difference between static pressure and setpoint was 0.2”.
  
  - **RTU zone static pressure:** All RTUs appeared to not meet their respective zone static pressure setpoints by ~0.06”.

  - **RTU-2 high mixed air temperature:** The mixed air temperature of RTU-2 was unusually high at 86.2F when both the return air and outdoor air temperatures were below 68F.

  - **Temperature rise in HWR loop:** An unusual temperature rise of 31F was noticed within the HWR loop. Possible causes include sensor miscalibration or the HW supply loop is leaking into the return loop.

Figure 16 shows a screenshot from the healthcare building EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons: A determination should be made whether all boiler pumps are required to be on when only one boiler is running.
Figure 17 shows another screenshot from the healthcare building EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- The mixed air temperature of RTU-2 appears to be unusually high when compared with the return air and outdoor air temperature.

- It appears that each RTU is not meeting their respective static pressure setpoint.

- It appears that each RTU is not meeting their respective space static pressure setpoint, resulting in all the exhaust fans to be commanded off. This could be a calibration issue.
Figure 18 shows another screenshot from the healthcare building EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:
- The supply air temperature is outside the bounds of the supply air setpoint specified by the reset schedule. The maximum supply air setpoint is specified to be 65F while the current supply air temperature is ~70F.

- Both the duct and space static pressures are not meeting their respective setpoints.

Figure 18: Screenshot 3 from the Healthcare Building EMS
Figure 18 shows another screenshot from the healthcare building EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- There appears to be an unusual temperature rise of 31°F in the HWR loop which might be a sensor miscalibration.
- It is not clear why the boiler supply temperature is set to 121°F when the HWS is 157°F.

**Figure 19: Screenshot 4 from Healthcare Building EMS**

Figure 20 shows another screenshot from the healthcare building EMS system. The B2Q team could not figure out what Unclear what 73.5°F is referencing.

Figure 20 shows another screenshot from the healthcare building EMS system. The B2Q team could not figure out what Unclear what 73.5°F is referencing.
Figure 21 shows another screenshot from the healthcare building EMS system. The B2Q team noticed that some zones are operating at temperatures as low as 64°F and wondered if these temperatures would be acceptable for building occupants.
Figure 21: Screenshot 6 from Healthcare Building EMS
1.4 Office Building

The findings from B2Q’s analysis of screenshots from an EMS system installed in an office building included:

- **Was adequate information provided?** No, the screenshots provided did not include information on all RTUs and their respective schedules for each floor.

- **Was equipment operating optimally?** Some issues were identified based on the limited screenshots received. The key issues are listed below. However, additional findings are listed with the individual screenshots.
  
  - **SAT greater than SPT:** The supply air temperature for RTU1 & RTU2 is ~12F greater than the supply setpoint of 60F.
  
  - **Building pressure lower than expected:** The building pressure is operating at about neutral while the building pressure setpoint is 0.05” positive.

  - **Airflow detected with damper fully closed:** The damper shown in Figure 24 is commanded fully closed. During this time the airflow station is reading 471 cfm of airflow while the airflow setpoint is 100 cfm.

Figure 22 shows one of the screenshots from the office’s EMS. The B2Q team concluded that to allow for a more complete screenshot analysis, it would have been helpful to provide screenshots of the RTUs and their schedules for each floor.
Figure 23 shows a screenshot from the office building EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- Building pressure is not meeting setpoint by 0.05”.
- The difference between the supply temperature and setpoint is unusually high.
- It is not clear if “damper” is indicating the mixing damper position or the outdoor damper position. It appears that the unit may be supplying mostly return air when the unit could mix outdoor air to the supply to meet supply temperature setpoint.
- It is not clear why the supply air setpoint is set to 60F
Figure 23: Screenshot 2 from Office Building EMS

Figure 24 shows another screenshot from the office building EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:
• Box damper is fully closed but airflow station is reading 471 cfm, 371 cfm greater than the airflow setpoint.

• It is not clear why the airflow is represented as being measured at the inlet of the box.
Figure 24: Screenshot 3 from Office Building EMS
1.5 Ski Resort

The findings from B2Q’s analysis of screenshots from an EMS system installed in a ski resort included:

- **Was adequate information provided?** No, the screenshots provided did not include information for RTU-1, 2, 11, & 13, MAU-5, exhaust fans, and any VAV boxes.

- **Was equipment operating optimally?** Some issues may be present based on the limited screenshots received. The key issues are listed below. However, additional findings are listed with the individual screenshots.
  - **Duct static pressure below setpoint:** The duct static pressure for RTU-3 & 15 was reading 0.41” below the static pressure setpoint.
  - **Supply air temperature above setpoint:** The supply air temperature for RTU-14 was reading 18F higher than the supply air setpoint.
  - **Minimum damper position:** The outdoor air damper position for RTU-8 is set to 0% open when the minimum damper position should be set to 10%.
  - **Heating alarm:** The heating alarm has been activated for RTU-3.
  - **Possible leaking cooling coil:** The supply temperature for RTU-3 is ~2F below the return air temperature with both heat command 1 & 2 on and the cooling command off. This may indicate that the cooling coils are leaking, or the supply air temperature sensor is mis-calibrated.

Figure 25 shows one of the screenshots from the ski resort EMS. The B2Q team concluded that to allow for a more complete screenshot analysis, it would have been helpful to provide screenshots for each RTU and MAU, exhaust fans, zone status and baseboard, and VAVs for each zone.
Figure 25: Screenshot 1 from Ski Resort EMS

Figure 26 shows another screenshot from the ski resort EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- Duct static pressure is 0.31" below static pressure setpoint.
- There appears to be no reference to OA damper position or supply air flow.
Figure 27 shows another screenshot from the ski resort EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- The supply air temperature is 18°F higher than the setpoint.
- There appears to be no reference to mixed air temperature and heat exchanger entering and leaving temperatures for both the exhaust and incoming air. These points would be useful in evaluating the operation of the heat exchanger and the economizer.
- A return air temperature point was not found.
Figure 28 shows another screenshot from the ski resort EMS system. The B2Q team observed that the unit cycles frequently during unoccupied hours and that it was not clear if the heat command turns off when the zone reaches the Efficient Heat Setpoint. It also noted that operating the heat command until the zone temperature reaches the Zone temperature would reduce cycling of the unit and lengthen the operating life of the heating/cooling valves.
Figure 28: Screenshot 4 from Ski Resort EMS

Figure 29 shows another screenshot from the ski resort EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- There appears to be no reference to mixed air temperature and heat exchanger entering and leaving temperatures for both the exhaust and incoming air. These points would be useful in evaluating the operation of the heat exchanger and the economizer.

- A return air temperature point was not found.

- The relationship between the effective setpoints, zone temperature setpoints, and the user adjust/slide is unclear.
Figure 30 shows another screenshot from the ski resort EMS system. The B2Q team observed that the unit cycles frequently during unoccupied hours and it should be determined whether the heat command turns off when the zone reaches the Efficient Heat Setpoint. The team noted that operating the heat command until the zone temperature reaches the Zone temperature would reduce cycling of the unit and lengthen the operating life of the heating/cooling valves.
Figure 31 shows another screenshot from the ski resort EMS system. The B2Q team observed that the outdoor air minimum position is set to 10% but the OA damper is reading fully closed. It is unclear if a similar issue is occurring with RTU-14 as well (see Figure 28).
Figure 32 shows another screenshot from the ski resort EMS system. The B2Q team noted that they did not see any reference to supply or return airflows. They also said that a determination should be made if the OA damper needed to be 100% open since less heating energy would be needed if the OA dampers did not have to be open 100% with a demand-controlled ventilation strategy.
Figure 33 shows another screenshot from the ski resort EMS system. The B2Q team concluded that this equipment is not operating optimally for the following reasons:

- A heating alarm has been enabled.
- The duct static pressure is 0.41” below the static pressure setpoint.
- Zone Temperature setpoints do not appear to be referenced in this screenshot.
- It is not clear why the HRU supply temperature is greater than the return air temperature. The supply air temperature is lower than both the return air temperature and the HRU supply temperature with the cooling coil deactivated (off). This may indicate that the supply air temperature is mis-calibrated or the cooling coil is leaking.
Figure 33: Screenshot 9 from ski resort EMS